



## METHOD FOR MANUFACTURING BEVEL GEARS

### BACKGROUND OF THE INVENTION

#### 5 1. Field of the Invention

The invention relates to methods for manufacturing toothed gears and, more particularly, to a method for manufacturing bevel gears with reduced runout by using the gear tooth top lands as a datum.

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#### 2. Background of the Invention

The traditional methods for manufacturing bevel gears with shafts involves several steps. First, a rough forging or bar stock would be machined into a blank which would include center bores used as manufacturing location points, or datums. The blank could include threads or splines as needed, or threads or splines could be added at a later operation. After blanking, the gear teeth are cut into the workpiece.

Spiral bevel and hypoid gear pairs are conventionally produced utilizing either an intermittent index face milling method or a continuous indexing face hobbing method. Until recently, face milling of gear teeth was the preferred method. The face hobbing process has been recently adopted by some gear manufacturers, especially those gear manufacturers who make the spiral bevel and hypoid gear sets for vehicular applications. In a face hobbing machine, a circular face hob type rotary cutter carrying a plurality of cutter blades mounted in

groups, is utilized, and a workpiece (gear blank) and the cutter continuously rotate in a timed relationship until the entire part is completed. During the cutting process, the workpiece indexes in a rotary manner so that each successive cutter blade groups engaging successive tooth slots as the gear or pinion member is being cut. The face hobbing method requires fewer  
5 production steps and less production time than the face milling method.

Normally, the tooth top lands of the gear teeth are not machined at the same time as the gear tooth profiles are cut, which incurs a great deal of eccentricity between a gear teeth pitch line and the top land. Surfaces such as centers had to be added to the gears, or expensive and complicated equipment such as gear pitch line chucks had to be purchased and maintained  
10 for machining the gears.

Thus, there is a need for an improved method for manufacturing bevel gears that overcomes shortcomings of the conventional independent drive axles.

## SUMMARY OF THE INVENTION

15 The present invention provides a novel method for manufacturing bevel gears. The method in accordance with the present invention comprises the steps of providing a bevel gear blank having a gearhead, forming gear teeth on the gearhead of the bevel gear blank by simultaneously cutting gear tooth top land, gear tooth side profile and a bottom land to form  
20 an unfinished bevel gear member using a face hobbing process, and machining at least one selected surface of the unfinished bevel gear member using the top lands of the gear teeth as a datum for centering the unfinished bevel gear member, thus forming a finished product. The

method is applicable for manufacturing the bevel gear member both with shaft axially extending from the gearhead and without the shaft.

Therefore, the present invention represents a novel arrangement of the method for manufacturing bevel gears. Forming gear teeth by simultaneously cutting gear tooth top land, gear tooth side profile and a bottom land to form an unfinished bevel gear member provides virtually no eccentricity between the gear tooth top lands and the gear bottom lands, and machining at least one selected surface of the unfinished bevel gear member using the top lands of the gear teeth as a datum for centering the unfinished bevel gear member. As a result, the bevel gear members manufactured in accordance with the present invention exhibit substantially reduced runout with a simpler set-up, require simpler, less expensive tooling to machine the gear members, which is easier to keep aligned for eccentricity and much easier to maintain. The runout can be set so as to reduce vehicle noise levels.

Moreover, cutting the gear tooth top land simultaneously with the gear tooth side profile eliminates of a subsequent manufacturing operation improves the consistency and accuracy of a gear teeth pith line runout, and part quality, as well as reduces manufacturing costs. In addition, the gear cutter blade of the present invention allows for greater manufacturing flexibility, as the cutting edge dimensions can be easily modified, and provides an ability to machine near-net forged parts without requiring precision control of the tooth top land during a blanking operation.

## BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the invention will become apparent from a study of the following specification when viewed in light of the accompanying drawings, wherein:

5        Fig. 1 is a side view of a workpiece in accordance with the preferred embodiment of the present invention;

Fig. 2 is a side view of the workpiece in accordance with the preferred embodiment of the present invention supported by a centering ring;

10       Fig. 3 is a side view of a unitary gear blank in accordance with the preferred embodiment of the present invention;

Fig. 4 is a side view of an unfinished bevel gear member in accordance with the preferred embodiment of the present invention;

Fig. 5A is a partial perspective view of a gearhead of the unitary gear blank on which a cutter blade is operating in accordance with the present invention;

15       Fig. 5B is a view of the cutter blade of Fig. 5A illustrating geometry of a cutting edge thereof;

Fig. 6 is a simplified sectional view of showing a gear tooth cutting operation performed on a face hobbing machine in accordance with the preferred embodiment of the present invention;

20       Fig. 7 is a side view of the unfinished bevel gear member supported by the centering ring and a rear spindle during a finish machining operation in accordance with the preferred embodiment of the present invention;

Fig. 8 is perspective view of a bevel gear member manufactured in accordance with the preferred embodiment of the present invention;

Fig. 9 is a side view of ring gear in accordance with the alternative embodiment of the present invention supported by the centering ring during a finish machining operation.

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## DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The preferred embodiment of the present invention will now be described with the reference to accompanying drawings.

10 The present invention is related to a method for manufacturing bevel gears. The preferred embodiment of the present invention describes a process for manufacturing a bevel gear member having a shaft adapted to support the gear member within a gear casing, such as a hypoid and/or spiral pinion drive gear member used for final drive assemblies of vehicular drive axles. It will be appreciated that the method for manufacturing bevel gears of the  
15 preferred embodiment of the present invention may be used for manufacturing of any bevel gear member including a gearhead with any appropriate tooth profile, such as spiral, hypoid, straight, etc., and a shaft.

The method for manufacturing bevel gears with shafts in accordance with the preferred embodiment of the present invention involves several steps.

20 First, a rough workpiece 10<sub>1</sub> illustrated in Fig. 1, is formed by forging, casting or any other appropriate manner known in the art. Preferably, the workpiece 10<sub>1</sub> is a unitary, single-piece metal part made, preferably, by forging. The workpiece 10<sub>1</sub> has a gearhead 12<sub>1</sub> and a

shaft 15<sub>1</sub> coaxially extending from the gearhead 12<sub>1</sub>. The workpiece 10<sub>1</sub> has a centerline 11 extending between a front end 24 and a rear end 26. The shaft 15<sub>1</sub> of the workpiece 10<sub>1</sub> is further provided with a first bearing seat portion 16<sub>1</sub>, a second bearing seat portion 18<sub>1</sub>, a rear portion 20<sub>1</sub> and a tail portion 22<sub>1</sub> of varying diameters. The gearhead 12<sub>1</sub> of the workpiece 10<sub>1</sub> has a face angle surface 14<sub>1</sub> and a rear face surface 13<sub>1</sub>.

As illustrated in Fig. 2, the workpiece 10<sub>1</sub> is then machined while supported by a centering ring (or locator) 28 engaging the face angle surface 14<sub>1</sub> of the gearhead 12<sub>1</sub> of the workpiece 10<sub>1</sub>. During the machining operation, excess material is removed from the shaft 15<sub>1</sub> and the rear face surface 13<sub>1</sub> of the gearhead 12<sub>1</sub> of the workpiece 10<sub>1</sub>, thus forming a unitary gear blank 10<sub>2</sub> shown in Fig. 3, ready for tooth cutting operation. The excess material removed during the machining operation is shown in phantom line in Fig. 2 and is generally designated by the reference numeral M.

As illustrated in Fig. 3, the unitary gear blank 10<sub>2</sub> has a gearhead 12<sub>2</sub> and a machined shaft 15<sub>2</sub> coaxially extending from the gearhead 12<sub>2</sub>. The shaft 15<sub>2</sub> of the gear blank 10<sub>2</sub> is further provided with a first bearing seat portion 16<sub>2</sub>, a second bearing seat portion 18<sub>2</sub>, a rear portion 20<sub>2</sub> and a tail portion 22<sub>2</sub> of varying diameters. It will be appreciated that the rear portion 20<sub>2</sub> of the gear blank 10<sub>2</sub> may include splines 21, while the tail portion 22<sub>2</sub> may have threads 23, formed as needed during the previous step of forming the unitary gear blank 10<sub>2</sub>. Alternatively, the splines 21 and/or threads 23 could be added at a later operation. The unitary gear blank 10<sub>2</sub> also includes a rear center bore 29 formed at the rear end 26 thereof used as manufacturing location points, or datums. The rear center bore 29 is provided to receive a centering pin 52 of a rear spindle 50 (shown in Fig. 7) to fully support the gear blank 10 on a

machine tool. The gearhead 12<sub>2</sub> of the unitary gear blank 10<sub>2</sub> has the face angle surface 14<sub>1</sub> and a machined rear face surface 13<sub>2</sub>.

After blanking operation, a plurality of gear teeth 32 are cut into the gear blank 10<sub>2</sub> in order to form an unfinished bevel gear member 10<sub>3</sub> of the present invention illustrated in Fig.

5 4. As shown, each gear tooth 32 includes pair of opposite side profiles 34 a top land 36. The gear teeth 32 are separated by a bottom land 38. As further illustrated in Fig. 5, the gear teeth 32 are cut with gear cutter blades 40 (only one is shown in Fig. 5A) provided to cut the top land 36 of the gear tooth 32 simultaneously with the side profile 34 thereof and bottom land 38. Such a method is disclosed in US Patent No. 6,536,999 which is assigned to the assignee  
10 of the present application and is hereby incorporated by reference into the present application.

As illustrated in Fig. 5B, the cutter blade 40 includes a shank 42 and a cutting member 44 formed at a distal end 43 thereof. A front face of the cutting member 44 of the cutter blade 40 is provided, generally only on one side thereof, with a cutting edge 45. The cutting edge 45 comprises a first section 46 for cutting the side profile 34 of the gear tooth 32, and a second  
15 section 47 for cutting the top land 36 of the gear tooth 32. Thus, the first section 46 defines a tooth side profile cutting edge and the second section 47 defines a tooth top land cutting edge.

The first section 46 of the cutting edge 45 extends from a tip 48 of the cutting member 44 at a predetermined axial pressure angle B. The axial pressure angle B of the first section 46 of the cutting edge 45 obviously depends on the angle desired for the sides of the gear teeth.  
20 As used herein, "axial pressure angle" is defined as the angle between the first section 46 of the cutting edge 45 and a central axis 41 of the cutter blade 40. The second section 47 of the cutting edge 45 is characterized by a width W, as illustrated in Fig. 5C. A distance C from the

tip 48 of the cutting member 44 to an intersection of the first section 46 and the second section 47 of the cutting edge 45 is a height of the first section 46 of the cutting edge 45 of the cutting member 44. The distance C is substantially equal to a whole depth of the gear tooth 32.

Thus, the gear cutter blade 40 cuts the side profile 34 of the gear tooth 32 by means of  
5 the first section 46 of the cutting edge 45, and simultaneously forms at least a substantial portion of the tooth top land 36 of the gear tooth 32 by means of the second section 47 of the cutting edge 45. The second section 47 of the cutting edge 45 may be dimensioned to cut an entire tooth top land 36 of the gear tooth 32, as illustrated in Figs. 5A and 5B.

Cutting the gear tooth top land simultaneously with the gear tooth side profile  
10 eliminates of a subsequent manufacturing operation improves the consistency and accuracy of a gear tooth whole depth, and part quality, as well as reduces manufacturing costs. In addition, the gear cutter blade of the present invention allows for greater manufacturing flexibility, as the cutting edge dimensions can be easily modified, and provides an ability to machine near-net forged parts without requiring precision control of the tooth top land during a blanking  
15 operation.

Preferably, as illustrated in Fig. 6, during the gear teeth cutting operation, the shaft 15<sub>2</sub> of the gear blank 10<sub>2</sub> is held by a collet chuck 56 and the gear teeth 32 are cut by a face hobbing process on a face hobbing machine 60.

During the teeth cutting operation, illustrated in Fig. 6, excess material is removed  
20 from the face angle surface 14<sub>1</sub> of the gearhead 12<sub>2</sub> of the gear blank 10<sub>2</sub>, thus forming the unfinished bevel gear member 10<sub>3</sub> shown in Fig. 4, including a gearhead 12<sub>3</sub> having a plurality of gear teeth 32. It will be appreciated that any appropriate tooth profile may be formed during



the teeth cutting operation, such as spiral, hypoid, straight, etc.

One of ordinary skill in the art will appreciate that a face angle surface 14<sub>2</sub> of the gearhead 12<sub>3</sub> of the bevel gear member 10<sub>3</sub>, shown in Fig. 4, is defined by the tooth top lands 36 of the gear teeth 32. Furthermore, since the gear tooth top lands 36 are machined at the same machine and by the same cutter blade as the gear tooth side profiles 34, the tooth top lands 36 and bottom lands 38 are extremely concentric. Thus, the top lands 36 of the gear teeth 32 (or the face angle surface 14<sub>2</sub> of the gearhead 12<sub>3</sub>) may be employed as a manufacturing datum and/or manufacturing locating surface at subsequent machining operations. In other words, the top lands 36 of the gear teeth 32 cut during the above manufacturing step are extremely concentric with a pitch of the gear teeth 32 so that any runout in the centering ring (or locator) 28 which rests on the top lands 36 of the gear teeth 32 will place precisely that amount of runout into the pitch of the gear teeth when measured from the centerline 11 of the regardless of the runout induced by other operations. The locating surface in the form of the top lands 36 of the gear teeth 32 (or the face angle surface 14<sub>2</sub>) can be easily checked for runout and wear using a standard indicator gage.

The next step after the gear teeth cutting operation is to heat treat the unfinished gear member 10<sub>3</sub> using various common heat treatment methods. The hardened by the heat treatment gear teeth 32 are stronger and wear better than soft gear teeth. The shaft 15<sub>2</sub> has better torsional strength after the hardening operation. Typically after heat treatment, hypoid and spiral bevel gears with shafts are straightened if necessary.

Lastly, a final machining operation or operations where the bearing seat portion 16<sub>2</sub> and 18<sub>2</sub> of the unfinished bevel gear member 10<sub>3</sub> are finish machined. During the final

machining operation, as illustrated in Fig. 7, the unfinished bevel gear member 10<sub>3</sub> is supported by the centering ring (or locator) 28 which rests on the top lands 36 of the gear teeth 32 (or the face angle surface 14<sub>2</sub>) of the gearhead 12<sub>3</sub> and the centering pin 52 of the rear spindle 50 engaging the rear center bore 29 in the rear end 26 of the unfinished bevel gear member 10<sub>3</sub>. The unfinished bevel gear member 10<sub>3</sub> is driven by the centering ring 28 through a driving pin 28a engaging the gear teeth 32.

Thus, the top lands 36 of the gear teeth 32 are used as a locating datum on one end of the unfinished bevel gear member 10<sub>3</sub>. On the other end of the unfinished bevel gear member 10<sub>3</sub>, the centering pin 52 of the rear spindle 50 is used as a locating datum. Alternatively, a spline pitch diameter is used as a locating datum. If a spline major diameter needs to be machined at this time, as is becoming more common for reduced drive shaft runout, the shaft 15<sub>2</sub> is blanked in such a manner that a diameter of the rear portion 20<sub>2</sub> is small enough in blanking as to not require machining after heat treatment.

The post heat treatment machining operations form a finished product - a bevel gear member 10 illustrated in Fig. 8. Preferably, as shown in Fig. 8, the bevel gear member 10 is a pinion drive gear, such as used for final drive assemblies of vehicular drive axles. Those of ordinary skill in the art will appreciate that the method for manufacturing bevel gears of the preferred embodiment of the present invention may be applicable for manufacturing of any bevel gear member including a gearhead with any appropriate tooth profile, such as spiral, hypoid, straight, etc., and a shaft.

Alternatively, the method of the present invention is applicable for manufacturing shaftless gear members, such as a ring gear member 110 having a substantially annular

gearhead 112. Gear teeth 132 of the gearhead 112 of the ring gear member 110 are cut with gear cutter blades provided to cut top lands 136 of the gear teeth 132 simultaneously with side profiles thereof and bottom lands using a substantially the same cutting process as in the preferred embodiment of the present invention described hereinabove. After the teeth 132 are cut, the ring gear member 110 is hardened using various common heat treatment methods. Then the post heat treatment, or final, machining operation or operations can be simplified (Fig. 9) giving similar advantages as stated for the gear member with the shaft. More specifically, during the final machining operation, as illustrated in Fig. 9, the ring gear member 110 is supported by the centering ring (or locator) 128 which rests on the top lands 136 of the gear teeth 132 (or a face angle surface 114) of the ring gear member 110 and a self-centering chuck 129 engaging an outer peripheral surface 115 of the ring gear member 110. Thus, the top lands 136 of the gear teeth 132 are used as a locating datum on one end of the ring gear member 110. In this position, an inner peripheral surface 116 and/or a rear face surface 113 of the ring gear member 110 is finish machined.

Therefore, the present invention represents a novel arrangement of the method for manufacturing bevel gears including the steps of forming gear teeth by simultaneously cutting gear tooth top land, gear tooth side profile and a bottom land to form an unfinished bevel gear member, thus providing virtually no eccentricity between the gear tooth top lands and the gear bottom lands, and machining at least one selected surface of the unfinished bevel gear member using the top lands of the gear teeth as a datum for centering the unfinished bevel gear member. As a result, the bevel gear members manufactured in accordance with the present invention exhibit substantially reduced runout with a simpler set-up, require simpler,

less expensive tooling to machine the gear surfaces, which is easier to keep aligned for eccentricity and much easier to maintain. The runout can be set so as to reduce vehicle noise levels.

The foregoing description of the preferred embodiments of the present invention has  
5 been presented for the purpose of illustration in accordance with the provisions of the Patent Statutes. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Obvious modifications or variations are possible in light of the above teachings.

The embodiments disclosed hereinabove were chosen in order to best illustrate the principles of the present invention and its practical application to thereby enable those of ordinary skill  
10 in the art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated, as long as the principles described herein are followed. Thus, changes can be made in the above-described invention without departing from the intent and scope thereof. It is also intended that the scope of the present invention be defined by the claims appended thereto.